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Characterization and Classification of Major Mango-growing Soils in Arid Part of Ananthapuramu District, Andhra Pradesh, India

R. Srinivasan*, R. Vasundhara, M. Lalitha, B. Kalaiselvi, K.V. Niranjana and Rajendra Hegde

National Bureau of Soil Survey & Land Use Planning (ICAR) Regional Centre, Hebbal, Bengaluru-560024, Karnataka

Abstract: Four typical pedons representing major mango growing soils, developed from granite gneiss parent material were studied for their morphological, physical and chemical properties. The soils were moderately shallow (50-75 cm) to very deep (>150 cm) in depth, loamy sand to sandy clay loam in texture, sub-angular blocky in structure, reddish brown to dark red in colour, slightly acidic to moderately alkaline in reaction, non-saline, very low to high in organic carbon content (0.09 to 1.29%), low AWC (3.36 to 7.80%), low to medium in cation exchange capacity (2.90 to 19.36 cmol (p^+) kg^{-1}) and high base saturation (78 to 98%). The soils also had high amounts of coarse fragments in P1 and P2 and high clay content in P4 and P2. Among the exchangeable cations, calcium was found to be high in most of the soils, followed by magnesium, sodium, and potassium. Based on the soil characteristics, the mango growing soils were classified as *Typic Haplargids* and *Typic Paleargids* in subgroup level. Varying soil and site characters *i.e.,* poor rainfall, shallow soil depths, excess gravel contents, low AWC, poor nutrient status and severe soil erosion are limiting the growth and development of mango plantation. Developing site-specific soils based suitable management practices can improve the productivity of mango crops.

Key words: *Mango, soil characterization, classification, arid region and argillic horizon*

Introduction

Mango is regular cultivated fruit in tropical and sub-tropical regions and grown in more than 100 countries (Mukherjee and Litz 2009). It is ranked as the second most cultivated tropical fruit and sixth major fruit crop worldwide and it has a high potential under climate change scenarios (Grechi *et al.* 2013). In India, mango is cultivated in an area of 22.62 lakh ha with an annual production of 196.86 lakh MT during 2016-17 (Indian Horticulture Database 2018). Most of the mango growers in the southern states of Andhra Pradesh, Karnataka, and Tamil Nadu account for 41.3% of the total area and 41.7% of total production in India. In South India, the productivity of mango orchards is low (5.53 t ha^{-1} in Kerala to 9.50 t ha^{-1} in Andhra Pradesh) when compared to other parts of the country (16.84 t ha^{-1} in Punjab and 17.14 t ha^{-1} in Uttar Pradesh) (Naik 2014). The production efficiency of mango orchards varies, which can be attributed partially to variations in soil resources and the environment (Reddy *et al.* 2001).

The mango is best adapted to a warm tropical monsoon climate with a pronounced dry season (>3 months) followed by rains. However, information from other countries indicates that crops cultivated for a long time over an extended area show a high degree of diversity due to varied environmental influences. The trees thrive well in light texture deep soils (at least above

*Corresponding author: (Email: srinivasan.surya@gmail.com)

100 cm), appropriate rainfall (500-1000 mm), good drainage, suitable altitude (0-1200 m), and preferably soil reaction (pH) between 5.5 and 7.5, even though, mango is tolerant to drought, occasional flooding, and poor soil condition (Ahmad *et al.* 2018). The ability of soils to supply nutrients and maintenance of soil physical conditions virtually determines the productivity of different soils. A proper understanding of morphological, physical, and chemical characteristics of the mango growing soils in the arid region is key indicators for sustainable productivity and to overcome the drought problems. Therefore, a case study was undertaken in part of Ananthapuramu district to evaluate the soil properties of mango growing soil to suggest suitable management practices for better production.

Table 1. Site characteristics of study area

Pedons	Series	Area covering (ha)	Landform	Erosion	Slope %	Run-off	Management
P1	Mallapalle (MLP)	506	Moderately sloping upland	Medium	1-3	Medium	Low
P2	Mittapalle (MTP)	747	Gently sloping upland	Severe	3-5	Rapid	Low
P3	Venkatapuram (VKP)	42	Leveled lowland	Slight	0-1	Medium	Medium
P4	Gajukuntapalle (GKP)	518	Gently sloping dyke side slope	Severe	3-5	Rapid	Medium

Materials and Methods

Study area

A case study was undertaken during 2018-19 in 3 Panchayats (Ingaluru, Venkatapuram, and Thummalakuntla Palle) from Obuladevaracheruvu Mandal, Kadiri, Ananthapuramu district in the Rayalaseema region of Andhra Pradesh covering 4822 ha area (Fig. 1). The study area comes under the Deccan plateau of the Rayalaseema region and lies between 14°0' to 14° 5' N latitude and 78°0' to 78° 3' E longitude and belongs to the agro-ecological region (AER) of 3. The major landforms of the area are hills, ridges, uplands, and low lands. Soil-site characteristics are given in table 1. Major crops grown in the study area are groundnut, bajra, sorghum, paddy, pulses, vegetables, mango and Jamun.

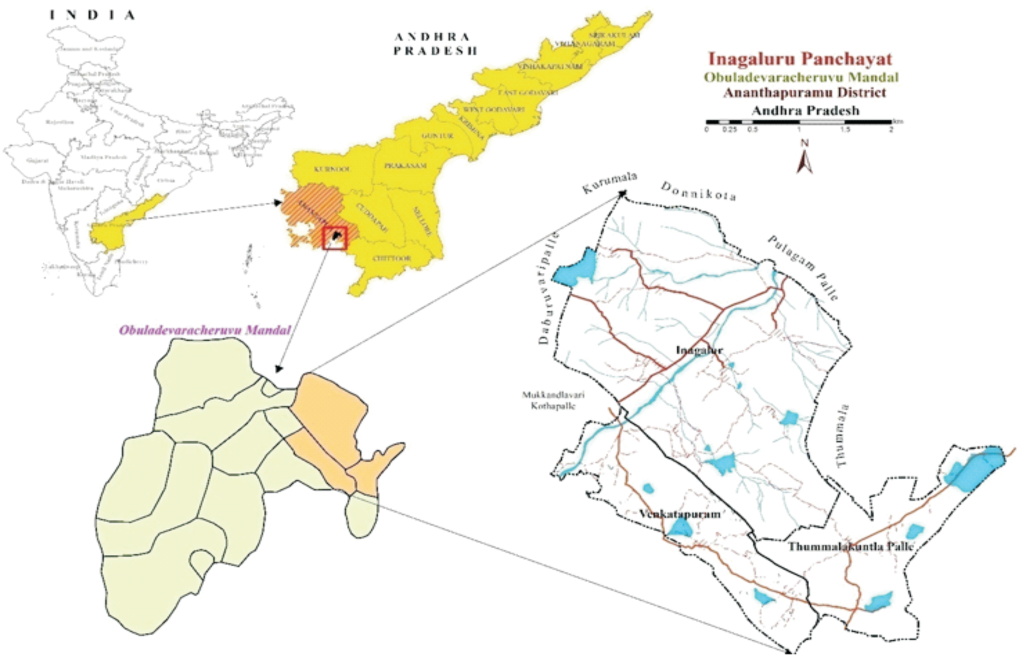

Fig. 1. Location map of the Study area

Climatic condition

The climate of the study area is arid and categorized as chronic drought-prone with an average annual precipitation of 580 mm, of which about 320 mm obtained during the southwest monsoon period from June to September (Fig. 2). North-east monsoon contributes about 190 mm from October to December and the remaining 70 mm is received during the rest of the year. The rainfall is erratic, uneven distribution, and varies between seasons with droughts being common. The mean temperature is above 23°C. April and May are the hottest months with mean temperatures between 32-35°C. Mean maximum temperature ranges from 30- 40°C in May and mean minimum temperatures ranged from 17-19°C in December months. The length of the growing period (LGP) is less than 90 days.

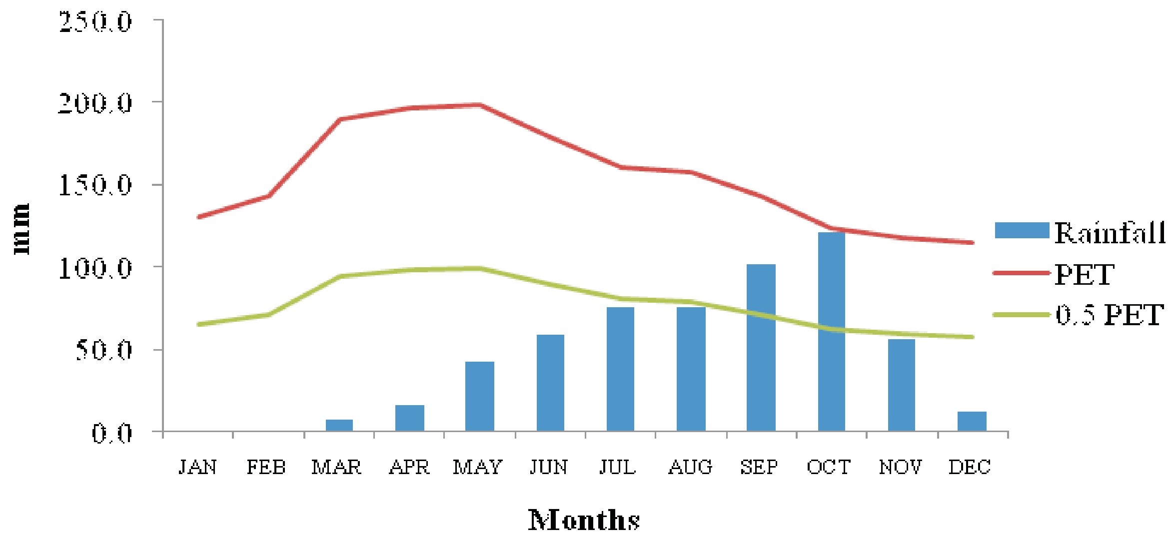

Fig. 2. Climatic condition of Inagalur cluster, Ananthapuramu district

Field studies

The detailed soil survey was carried out in 3 Panchayats (Inagalur, Venkatapuram and Thummalakuntla Palle) using village cadastral maps and IRS satellite (IRS LISS IV and Cartosat-1) imagery on a 1:10,000 scale. The false colour composites of IRS imagery were interpreted for physiography and these physiographic delineations were used as a base for mapping soils. The soils were studied in several transects and a soil map was prepared with phases of soil series as mapping units. Among the soil series identified, major soils found in mango plantation was taken as representing soil pedons for characterization, classification, and evaluation of their potential and problems. Totally one hundred seventy-five (175) soil profiles were studied in the 3 Panchayats and 19 soil profiles were studied from mango orchard, after grouping four soil series were established.

Soil analysis

The horizon-wise soil samples collected were air-dried, processed, sieved using a 2 mm sieve, and used for the determination of major soil properties. Particle-size distribution was determined by the international pipette method. Soil pH and EC were determined using the standard procedures described by Page *et al.* (1982). A pressure plate extractor was used for the characterization of soil moisture-retention and estimated the percentage of available water capacity (AWC) (Klute 1986). Soil organic carbon was determined by the wet oxidation method of the Walkley and Black (1934) method. Cation exchange capacity (CEC) was determined using 1 *N* ammonium acetate at pH 7.0, whereas, base saturation was calculated as the sum of bases divided by CEC and multiplied by 100. Exchangeable calcium (Ca) and magnesium (Mg) were extracted using 1 *N* ammonium acetate at pH 7.0 and measured in AAS (Jackson 1973). Available phosphorus in soil was determined following the ascorbic acid reduction method as outlined by Bray and Kurtz (1945). Available potassium was estimated by flame photometer after extraction with Neutral normal ammonium acetate solution (pH 7.0). The available sulphur was extracted by 0.15% $CaCl_2$ and estimated the sulphate content by turbidimetric procedure (Jackson 1973). Available Boron was estimated by using Azomethine-H reagent (Jackson 1973). The available micronutrients (Fe, Mn, Cu, and Zn) were extracted using DTPA (Lindsay and Norvell 1978) and their concentrations were determined using atomic absorption spectrophotometer. Land capability classes (LCC) (AISLUS 1970) criteria developed for mango were used to group soils into different management. The soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 2014).

Results and Discussion

Soil morphology

The solum depth varied from moderately shallow (50-75 cm) to very deep (>150 cm) and soils are well-drained. The surface soil matrix colour varied from dark reddish brown (2.5YR 3/4) to dark brown and brown, whereas, sub-soils were reddish-brown (5YR 4/3) to dark reddish brown (2.5YR 3/3) and dark red (2.5YR 3/6) (Table 2). The soil colour appears to be the function of chemical, mineralogical composition, as well as textural, make up of soils that conditioned by topographic position

Table 2. Morphological and physical characteristics of the Mango growing soils

Depth (cm)	Horizon	Colour (moist)	Sand	Silt (%)	Clay	Texture	Coarse fragments (%)	Structure	Consistence
P1:Mallapalle series: Clayey -Skeletal, mixed isohyperthermic Typic Haplargids									D M W
0-12	Ap	2.5YR 3/4	82.2	6.6	11.0	ls	27	f1 sbk	s vfr so/po
12-26	Bt1	2.5YR 3/6	67.9	9.0	23.0	scl	48	m 2 sbk	- fr ms/mp
26-94	Bt2	2.5YR 3/4	66.8	7.1	26.0	scl	60	m 2 sbk	- fr ms/mp
P2:Mittapalle series: Loamy-skeletal, mixed isohyperthermic Typic Paleargids									
0-13	Ap	7.5YR 3/4	86.7	8.6	4.6	ls	25	f1 sbk	s vfr ss/sp
13-31	Bt1	2.5YR 3/6	68.1	9.1	22.6	scl	50	m 2sbk	- fr ms/mp
31-62	Bt2	2.5YR 3/4	58.9	9.5	31.4	scl	60	m 1sbk	- fr ms/mp
P3:Venkatapuram series: Fine-loamy, mixed isohyperthermic Typic Paleargids									
0-16	Ap	7.5YR 4/3	77.5	9.5	12.9	sl	-	m 1 sbk	sh fr ss/sp
16-33	Bt1	10YR 4/3	73.0	9.7	17.2	sl	-	m 2sbk	- fr ms/mp
33-61	Bt2	5YR 4/3	70.4	8.6	20.8	scl	-	m 1sbk	- fr ms/mp
61-88	Bt3	5YR 4/3	65.6	12.3	22.0	scl	-	m 1sbk	- fr ms/mp
88-118	Bt4	5YR 4/4	65.8	12.0	22.0	scl	-	m 1sbk	- fr ms/mp
118-147	Bt5	5YR 4/4	65.6	11.6	22.7	scl	-	m 1sbk	- fr ms/mp
147-176	Bt6	5YR 4/4	67.7	10.7	21.4	scl	-	m 1sbk	- fr ss/sp
P4:Gajukuntapalle series: Loamy-skeletal, mixed isohyperthermic Typic Paleargids									
0-17	Ap	2.5YR 3/3	54.2	17.1	28.5	scl	15	m 1 sbk	s vfr ms/mp
17-42	Bt1	2.5YR 3/3	52.1	14.4	33.3	scl	28	m 1sbk	- fr ms/mp
42-60	Bt2	2.5YR 3/4	53.2	13.4	33.3	scl	38	m 1sbk	- fr ms/mp
60-84	Bt3	2.5YR 3/6	69.4	7.7	24.5	scl	48	m 1sbk	- vfr ms/mp
84-130	BC	2.5YR 3/6	67.6	8.8	21.6	scl	36	m 1sbk	- vfr so/po

Texture: ls- loamy sandy, sl- sandy loam, scl - sandy clay loam;
Structure: Size (S) - vf - very fine, f - fine, m - medium, c - coarse; Grade (G) - 0 – structure less, 1- weak, 2 - moderate, 3 - strong; Type (T) cr - crumb, sg - single grain, abk - angular blocky, sbk - sub-angular blocky; *Consistence*: Dry: s - soft, 1- loose, sh - slightly hard, h - hard Moist: 1- loose, vfr- very friable, fr - friable, fi - firm, vfi - very firm; Wet: so - non-sticky, ss - slightly sticky, ms – moderately sticky; po - non-plastic, ps – slightly plastic, mp – moderately plastic;

and moisture regime (Walia and Rao 1997). The prevailing high temperatures on granite parent materials caused a high weathering process and increasing the redness index of the soils. Coarse fragments varied in different depths, among them P1, P2 and P4 were highly gravelly (35 to 60%), whereas P3 was non-gravelly. The texture of the soils varied from loamy sand to sandy clay loam. This might be due to differences in the composition of parent material, topography, in-situ weathering, and translocation of clay by eluviation and age of soils (Srinivasan *et al.* 2016). The structure of soils was sub-angular blocky type. The dry consistency varied from soft to slightly hard, moist consistency from friable to very friable, and wet consistency from non-sticky/plastic to moderately sticky to moderately plastic. The presence of various structures and consistency of the soils is because of influences of clay fraction and clay minerals (Thangasamy *et al.* 2005).

Soil characteristics

Physical characteristics

Granulometric data revealed that the clay content varied from 11.0 to 33.3% (Table 2). The increasing trend of clay with depth was primarily due to the vertical migration of clay (Vedadri and Naidu 2018). Silt content, in general, exhibited an irregular trend with depth, which might be due to variation in weathering of parent material or in-situ formation (Satish *et al.* 2018). Sand constitutes the bulk of mechanical fractions, which could be attributed to the siliceous nature of granite-gneiss parent material. Water holding capacity (WHC) of different pedons varied from 3.36 to 7.80% (Table 3). These variations were due to the difference in clay, silt, and organic carbon content and low WHC in coarse texture (loamy sand and sandy loam) soils were due to high sand

Table 3. Physico-chemical characteristics of the Mango growing soils

Depth (cm)	pH (1:2.5)H_2O	EC (dS m^{-1})	AWC	OC	Exchangeable cations Ca	Mg	Na	K	Sum of cations	CEC	BS
					(*1 N* NH_40Ac, pH 7.0)						
			(%)		cmol (p^+) kg^{-1}						(%)
P1:Mallapalle series:Clayey -skeletal, mixed isohyperthermic Typic Haplargids											
0-12	6.9	0.07	4.82	0.18	3.55	1.77	0.05	0.13	5.5	5.9	93
12-26	7.0	0.06	5.08	0.18	6.70	3.12	0.11	0.09	10.0	10.7	94
26-94	7.1	0.05	5.63	0.14	7.50	2.95	0.26	0.08	10.7	11.7	92
P2:Mittapalle series:Loamy-skeletal, mixed isohyperthermic Typic Paleargids											
0-13	6.7	0.06	3.36	0.67	1.37	0.72	0.03	0.23	2.3	2.9	81
13-31	6.6	0.03	6.07	0.69	5.18	2.00	0.13	0.10	7.4	8.7	85
31-62	6.3	0.03	5.89	0.53	4.80	2.09	0.08	0.16	7.1	9.1	78
P3:Venkatapuram series :Fine-loamy, mixed isohyperthermic Typic Paleargids											
0-16	8.0	0.17	4.10	0.51	6.00	2.02	0.32	0.16	8.5	8.7	98
16-33	8.3	0.15	6.11	0.34	6.25	3.26	0.64	0.06	10.2	10.5	97
33-61	8.1	0.16	6.48	0.26	5.52	4.52	0.58	0.05	10.6	11.1	96
61-88	8.0	0.22	6.84	0.19	6.35	5.26	0.60	0.05	12.2	15.0	82
88-118	8.5	0.17	7.35	0.19	7.56	4.23	0.60	0.06	12.4	15.1	82
118-147	8.4	0.23	7.80	0.09	8.56	4.52	0.66	0.05	13.8	15.0	92
147-176	8.5	0.25	7.80	0.20	9.52	3.02	0.60	0.05	13.1	13.9	95
P4:Gajukuntapalle series:Loamy-skeletal, mixed isohyperthermic Typic Paleargids											
0-17	6.2	0.06	7.23	1.29	8.56	5.10	0.07	0.17	13.8	16.1	86
17-42	6.6	0.05	6.97	1.03	11.3	5.76	0.07	0.11	17.2	19.3	89
42-60	6.7	0.05	4.77	0.77	12.0	5.39	0.10	0.11	17.6	19.1	92
60-84	6.8	0.04	4.21	0.36	9.21	3.60	0.10	0.09	12.9	13.2	98
84-130	7.0	0.04	5.51	0.22	8.43	3.72	0.07	0.10	12.3	12.5	98

content. The irregular trend of WHC with depth was due to the clay and water movement from the surface to different lower horizons.

Chemical characteristics

All the pedons were slightly acidic to moderately alkaline with pH ranging from 6.26 to 8.53 (Table 3). This wide variation was attributed to the nature of the parent material, leaching, presence of $CaCO_3$, and exchangeable Na. All the pedons had shown low electrical conductivity (EC) values ranging from 0.03 to 0.25 dS m^{-1}, indicating non-saline nature. The low EC may be due to undulated topography causing wash of soil's salts during rainfall by percolating and drainage water (Surekha *et al.* 1997). The organic carbon content of the soils was found to medium to high on the surface (1.29%) and the least in the sub-surface soils (0.09%). The organic C content declined with depth in all the pedons. The low organic matter content in the soils might be due to the prevalence of tropical conditions, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic C in the soils (Srinivasan *et al.* 2020). High OC content was found in surface layers of P4, which is due to adjoining dyke landform, forest, and others bushes which helps in regular addition of plant debris to surface soils. Cation exchange capacity and base saturation varied from 2.90 to 19.36 cmol (p^+) kg^{-1} and 78 to 98%, respectively, which mostly corresponds to the clay content, organic C content, and also type of clay mineral present in the different horizons of soils. Exchangeable bases in all pedons were in the order of $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ on the exchange complex. The higher exchangeable Ca in the surface soil could be due to the redistribution of Ca by different plant species. The higher base saturation observed in almost all pedons might be due to the higher amount of Ca^{2+} occupying exchange sites on the colloidal complex. The differences in base saturation indicated the degree of leaching (Sharma *et al.* 2011).

Nutrient status

Macronutrients: The available P in soil was generally low and it varied from 2 to 31 kg ha^{-1} in different pedons. However, relatively high available P content was observed in the surface horizons and declined with depth (Table 4). It might be due to the confinement of crop residual management and supplementing the depleted P by external sources *i.e.,* fertilizers (Thangasamy *et al.* 2005). The lower P content in sub-surface horizons compared to surface horizon was due to the fixation of released P by clay minerals and oxides of iron and aluminum. Available K content of soils varied from 54 to 247 kg ha^{-1}. The highest available K content was observed in the surface horizons and showed a declining trend with depth. This might be attributed to more intense weathering, the release of labile K from organic residues, application of K fertilizers, and upward translocation of K from lower depths along with the capillary rise of groundwater. The available S and B in soils varied from 1.58 to 38.8 and 0.11 to 0.63 mg kg^{-1}, respectively. Available S and B are related to organic carbon and clay distribution in different horizons.

Micronutrients: The DTPA-extractable Zn ranged from 0.02 to 1.04 mg kg^{-1} soil. The vertical distribution of Zn exhibited little variation with depth. Considering 0.60 mg kg^{-1} as a critical level (Lindsay and Norvell 1978), these soils are deficient in available Zn. The low availabilty of Zn in soil was possibly due to high soil pH which might have resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate (Prasad *et al.* 2009).

All the pedons were sufficient in available Cu (0.28 to 2.92 mg kg^{-1}) as values were well above the critical limit of 0.20 mg kg^{-1} soil as suggested by Lindsay and Norvell (1978). The DTPA-extractable Fe content varied from 0.74 to 16.66 mg kg^{-1} soil. According to a critical limit of 4.5 mg kg^{-1} of Lindsay and Norvell (1978), the P1 and P3 soils were deficient and surface layers of P2 and P4 were sufficient in available Fe. The distribution of available Fe in all the pedons did not show a definite pattern but it decreased abruptly with depth. It might be due to the accumulation of organic C in the surface horizons. Surface horizons had higher concentrations of DTPA-extractable Fe due to higher organic C. Available Mn varied from 1.48 to 34.52 mg kg^{-1} soil and it decreased with depth. According to a critical limit of 1.0 mg kg^{-1} of Lindsay and Norvell (1978), the soils were sufficient in available Mn. Addition of mango plant litters on surface, which attributes more organic carbon status and making chelating of organic compounds to releasing the micronutrients. Soil organic carbon was highly correlated with soil parameter *viz.,* EC (0.532*), Exch Na (0.597**), Mg (0.570*), CEC (0.575*), and silt (0.542*) (Table 5), respectively.

Table 4. Nutrients status in different Mango growing soils

Depth (cm)	Macronutrients		Secondary and Micronutrients					
	P	K	S	B	Fe	Mn	Cu	Zn
	(Kg ha^{-1})		(mg kg^{-1})					
Pedon 1:Mallapalle series								
0-12	9	126	7.93	0.38	2.40	8.34	1.38	0.28
12-26	5	90	6.34	0.23	1.94	13.60	0.28	0.04
26-94	3	74	4.76	0.26	2.20	14.96	0.34	0.08
Pedon 2:Mittapalle series								
0-13	9	247	5.55	0.25	8.06	8.48	0.38	0.26
13-31	4	100	1.58	0.11	3.32	10.52	0.30	0.06
31-62	3	135	15.83	0.18	4.02	15.18	1.06	0.10
Pedon 3:Venkatapuram series								
0-16	31	195	15.83	0.15	1.56	4.14	0.44	0.36
16-33	5	77	15.83	0.17	1.76	2.72	0.48	0.08
33-61	3	63	26.66	0.63	1.48	2.38	0.46	0.02
61-88	3	64	32.50	0.28	1.72	2.16	0.58	0.04
88-118	4	59	27.50	0.41	1.02	1.74	0.50	0.04
118-147	6	54	7.50	0.45	0.74	1.48	0.40	0.06
147-176	2	64	15.83	0.37	0.96	1.48	0.48	0.04
Pedon 4:Gajukuntapalle series								
0-17	4	141	34.12	0.19	16.66	34.52	2.76	1.04
17-42	5	104	29.36	0.14	10.76	32.34	2.92	0.36
42-60	5	90	23.01	0.25	7.84	26.12	2.30	0.30
60-84	6	99	22.22	0.29	3.78	11.92	1.48	0.12
84-130	6	83	38.88	0.26	3.28	9.70	1.42	0.16

Table 5. Correlation between soil parameters and soil organic carbon

Soil Parameters	OC
pH	0.440
EC (dS m^{-1})	0.532*
AWC %	-0.044
Ex.Ca (cmol (p$^+$) kg^{-1})	0.396
Ex. Mg (cmol (p$^+$) kg^{-1})	0.570*
Ex. Na (cmol (p$^+$) kg^{-1})	0.597**
Ex. K (cmol (p$^+$) kg^{-1})	-0.599**
CEC (cmol (p$^+$) kg^{-1})	0.575*
BS %	-0.173
Sand %	-0.529*
Silt %	0.542*
Clay %	0.439

* Correlation is significant at the 0.05 level (2-tailed);
** Correlation is significant at the 0.01 level (2-tailed).

Soil classification

Based on morphological characteristics and soil properties of the typifying pedons, the soils were classified upto the family level according to Keys to Soil Taxonomy (Table 6). Mallapalle (P1) soil series was classified *Typic Hapargids* at subgroup level and others P2, P3 and P4 were classified *Typic paleargids.* Aridisols that have an argillic horizon and do not have a petrocalcic horizon within 100 cm of the soil surface qualifying Argids suborder. Paleargids great group based on argillic horizon that has 35 per cent or more non-carbonate clay throughout one or more sub-horizons in its upper part, with clay increase of 15 per cent or more within a vertical distance of 2.5 cm either within the upper boundary of soils.

Interpretative groupings

Soils were interpreted and evaluated for land capability for mango plantation considering based on climatic conditions, soil depth, texture, drainage, slope, presence of gravels, AWC, and fertility status, the soil were evaluated. Land capability assessment categorized the soils into Class III with limitations of erosion and soil limitations (Table 7). Major constraints encountered are shallow depth, severe soil erosion, aridity, low AWC, and poor soil fertility. Appropriate soil and water conservation measures and the addition of organic manures and fertilizers will overcome the limitations and improve the productivity of Mango plantations in arid regions of Andhra Pradesh.

Table 6. Classification of major Mango growing soils in the study area

Pedons	Series	Soil Taxonomy				
		Order	**Sub order**	**Great group**	**Sub group**	**Family**
P1	Mallapalle (MLP)	Aridsols	Argids	Haplargids	Typic Haplargids	Clayey -Skeletal
P2	Mittapalle (MTP)	Aridsols	Argids	Paleargids	Typic Paleargids	Loamy-skeletal
P3	Venkatapuram (VKP)	Aridsols	Argids	Paleargids	Typic Paleargids	Fine-loamy
P4	Gajukuntapalle (GKP)	Aridsols	Argids	Paleargids	Typic Paleargids	Loamy-skeletal

Table 7. Suitability evaluations and management of Mango growing soils

Pedons	**Series**	**Land capability class with limitations**	**Growth condition**	**Major limitations**	**Suggested land use & Management**
P1	Mallapalle (MLP)	IIIes	Poor	Gentle slope upland with moderately deep, moderate erosion, medium runoff and low AWC & soil nutrients status and high gravels content	Cultivation of alternate crops like pulses, oil seeds, legumes and suitable agro-forestry systems. Addition of manures and fertilizers and adopting appropriate soil conservation measures.
P2	Mittapalle (MTP)	IIIes	Poor	Gentle slope with moderately shallow depth, severe erosion, rapid run-off and low AWC & poor nutrients status and high gravels content	Climatically adopted cropping systems *viz.* pulses, oilseeds, agro - forestry and grass for animal feeding. Adopting agri based allied sector like cow, goat and sheep raring *etc.* Adopting appropriate soil and water conservation measures and nutrient management techniques.
P3	Venkatapuram (VKP)	IIIs	Moderate	Leveled low land with very deep soils, slight erosion, low AWC, OC, N, P, K, B, Fe, Mn & Zn	Adopting intercrop systems will be more beneficial. Adopting integrated nutrient and water management.
P4	Gajukuntapalle (GKP)	IIIes	Moderate	Gentle slope side slope of dyke with deep depth, severe erosion, rapid runoff and low AWC & poor nutrients status and medium gravel contents.	Special soil -conservation measures and encouraging intercropping systems, crop rotation (pulses, grasses and legumes) more sustainability. Adopting appropriate soil and water conservation measures and application of optimum dose of manures and fertilizers.

Conclusion

The present study characterized the mango growing soils and classified them under Aridisols soil order. Among the soil-forming factor, arid climate conditions, parent materials, topography, and land-use patterns had a major contribution to genesis. Results revealed that major limitation for mango production in this area is frequent drought due to aridity and uneven rainfall of distribution, shallow soil depths with excess gravel contents, low AWC, poor fertility status, and severe soil erosion. Sustainable mango production could be achieved through the selection of appropriate sites based on soil suitability for plantation and by adding adequate manures and fertilizers. Adopting appropriate site-specific soil and water conservation measures could reduce run-off, soil erosion, and nutrient loss which improve mango productivity.

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